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ABSTRACT

This paper examines various aspects of teaching science to visually impaired students. It is based on the premise that students with visual impairments should acquire scientific literacy and should be encouraged to pursue science-related careers. It is not designed to make science teachers specialists but to increase their awareness to the unique needs of visually impaired students. Topics addressed include: (1) curriculum efforts to develop alternative teaching methods and materials (such as Adapting Science Materials for the Blind (ASMB), Science Activities for the Visually Impaired (SAVI), and the Student Science Teaching Program in Marine Science for the Handicapped program; (2) the identification and selection of alternative techniques, focusing on close-up tasks, near-by tasks, distance tasks, and mobility tasks; (3) ways of providing hands-on experience and laboratory activities; (4) safety considerations related to mobility and orientation, using new instruments and techniques, work stations, and eye and face protection; (5) career education (which includes short descriptions of five visually-impaired individuals in the sciences); and (6) the use of computer technology in teaching science to visually impaired students. References to programs discussed and a list of resources are included in two appendices. (JN)

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SCIENCE FOR STUDENTS WITH VISUAL IMPAIRMENTS

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KENNETH S. RICKER

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INTRODUCTION

The focus of this monograph is on teaching science to students who are visually impaired. Notice that the previous sentence is not written "...teaching science to visually impaired students." It is essential that we place the emphasis on the proper word -- "students", and not on the words "visually" impaired." Too frequently we read about teaching the visually impaired or blind. In other words, we should be concerned with teaching science to students who happen to have some sort of visual impairment.

The needs for teaching science to these students are the same as those for teaching science to all students. Science is not a subject reserved for a chosen group of students. The goal of science education, to help students acquire scientific literacy, is equally important for students with vision impairments as those students with no visual problems.

Opportunities for all students who have the interest and aptitude to embark on science-related careers should be available. In the past, these career opportunities have not been readily available for students with visual impairments. Students with visual impairments have received little support or encouragement to pursue science studies enabling them to become an engineer, medical doctor, or science teacher.

Over the last fifteen years many efforts have been initiated in an attempt to make all aspects of science education accessible to students with visual impairments. These efforts have included the development of alternative teaching methods and materials. It is essential that alternative methods and materials be made available for science teachers who have students with visual impairments enrolled in their science classes. Several curriculum efforts to develop alternative teaching methods and materials are reviewed in the next section.

ALTERNATIVE TEACHING METHODS AND MATERIALS

The reader should refer to Appendix A for references that will provide detailed information about each of the curriculum efforts described in the section.

American Printing House for the Blind

The American Printing House for the Blind (APHB) is well known for its long history of making school textbooks and related literature available in braille, large print and audio formats. APHB also distributes many educational aids in an attempt to enhance the education of students with visual impairment. In the area of science these instructional aids include tactile diagrams, manipulative devices for measuring and for investigating simple machines, light sensor, and self-study science units. A catalog that describes available aids can be obtained from the American Printing House of the Blind, P. O. Box 6085, Louisville, KY 4026.

A variety of tactile diagrams (embossed schematics) that are read with the finger-tips have been developed. These diagrams

provide information that sighted students gain through the study of visual diagrams or observations. The tactile diagrams consist of raised symbols of various shapes and textures. The symbols are colored so students with residual vision can use visual and tactile reading techniques simultaneously to examine a diagram.

Examples of science diagrams for elementary school students include a pull-apart cell and an insect identification kit. The pull-apart cell depicts the cross-section of a typical plant and animal cell. The outer edge of the cell diagram which indicates the presence of an outer wall in a plant cell is removable. This permits the diagram to be used as a tactile illustration of a plant or animal cell. The symbol depicting the nucleus of the cell is also removable. The entire diagram is covered with a removable top.

The insect identification kit has five separate diagrams that enable students to study the parts of an insect, as well as the likenesses and differences among insects.

For secondary school science students there are nineteen tactile diagrams that illustrate invertebrate and plant phyla. The internal structure of a clam, ascon sponge, starfish, paramecium, root, leaf, and woody stem are examples of these diagrams.

Self-instructional units on cell division have recently been produced. Six tactile diagrams on mitosis and fourteen tactile diagrams on meiosis have been designed and tested. Each set of diagrams is accompanied with an audio cassette to guide the student's study of mitosis and meiosis. A large print and braille glossary is also included to assist the students.

The light sensor is an instructional aid that permits the students to conduct hands-on science activities. The sensor produces an auditory sound that will vary in pitch and volume when exposed to varying light conditions. For example, the variations in the clearness of several samples of water can be detected by the variation in the amount of light that passes through each sample. Or the change in color of food containing starch when drops of iodine solution are applied can be detected by the light sensor.

Instruments have been developed or modified to provide tactile readings when students need to measure linear dimensions, weight, mass or temperature. These aids enable students with visual impairments to gain an understnading of measurement skills and concepts.

Adapting Science Materials for the Blind (ASMB) and Science Activities for the Visually Impaired (SAVI)

In 1969 the Lawrence Hall of Science at the University of California, Berkeley, initiated efforts to adapt the Science Curriculum Improvement Study (SCIS), an elementary school science program, for use with students who are visually impaired. This project was called Adapting Science Materials for the Blind (ASMB). The project developed and evaluated alternative instructional materials and teaching strategies so these students could participate in the SCIS activities with their classmates who were not visually impaired.

For example, in the first grade SCIS unit, Organisms, the students observe acquaria containing guppies. The ASMB adaptation

provides an alternative activity to accomplish the same objectives. A goldfish about three inches long is placed in an aquarium that has an inner liner. This liner has holes in the bottom. When it is time for the student to observe the organism, the student slowly lifts up the liner and tilts it so the water drains out through the holes. This will leave the goldfish in a small trough of water along the bottom edge of the liner. The student can easily locate the goldfish with his fingers and gently touch it. It is also possible for the student to remove the goldfish from the water in a cupped hand for a couple of minutes and tactually examine the organism.

In the third grade SCIS unit, Subsystems and Variables, the students make histograms to make a record of their observations. For the ASMB adaptation the students use a sheet of "bubble paper" to make a histogram. The students depress a "bubble" to record a specific observation. The resulting histogram can be read tactually by reading the braille numbers on each axis and feeling for the depressed "bubbles".

The efforts involved in accomplishing the ASMB project provided much of the impetus for the creation of a new curriculum project in 1979; Science Activities for the Visually Impaired (SAVI). This project sought to design, evaluate and disseminate hands-on activities in science for students, ages 9 through 12, who are visually impaired.

The SAVI project resulted in the production of 9 modules with each module consisting of 4 to 8 different activities. These activities were designed so students could practice science process skills (observing, measuring, inferring, controlling

variables, etc.) and study selected science concepts (e.g., solar energy, magnetism, sound, animal and plant growth, environmental factors, evaporation).

For example, in the Structures of Life Module the students collect and analyze data as they study the structure and behavior of crayfish. Crayfish, a relatively large and slow moving animal, can endure handling and can be safely removed from the water for several minutes. Rubber tubing is placed on each pincer so the students can handle it without fear of getting pinched. Over a period of several weeks the students establish and maintain an appropriate habitat for the crayfish. During this time they investigate a variety of its behavioral traits. In the Mixtures and Solutions Module the students have many opportunities to manipulate a variety of materials as they study the concepts of mixtures, solutions, evaporation, filteration, and interaction. The students measure out specific amounts of liquids and solids, dissolve and filter materials, listen and smell for interactions between solutions, feel for residue, and measure temperature.

The remaining SAVI modules are: Scientific Reasoning, Communication, Environments, Measurement, Environmental Energy, Kitchen Interactions, and Magnetism and Electricity.

It should be noted that during the field testing of the SAVI materials evidence was obtained that teachers were using the SAVI materials with students who had other handicaps, particularly those students with learning disabilities and orthopedic handicaps. This evidence led to another project in which the SAVI materials were adapted for use with students with other handicaps. From this project came the program Science Enrichment for Learners

with Physical Handicaps, (SELPH). Further information on the SAVI/SELPH programs can be obtained by writing to the Lawrence Hall of Science University of California, Berkeley, CA 94720.

Biology for the Blind

In the early 1970's Dorothy Tombaugh, a high school science teacher, had students who were visually impaired enrolled in her biology classes. She immediately became involved in the problems of making her courses accessible to these students. Since that time her efforts have continually expanded to include many science courses and students with various handicaps.

One of Tombaugh's first projects resulted in a teacher's guide on adapting the BSCS Green Version High School Biology course for visually impaired students. For example, she found that genetic corn seedlings could be used in place of fruit flies which were normally used to investigate Mendelian genetics. In the investigation on the effect of an abiotic environmental factor on a population she found the use of hydra inappropriate. The students could conduct the investigation if a larger organism was substituted for the hydra. Mealworms and Elodea were found to be appropriate substitutions.

A one hour video tape, entitled "Science for the Handicapped", has recently been produced to present Dorothy Tombaugh's curriculum efforts in this area. Information on this tape can be obtained from the Instructional Media/TV Department, Emporia State University, Emporia, KS 66801.

Laboratory Science and Art for Blind, Deaf and Emotionally Disturbed Children in a Mainstream Setting

This curriculum project was multi-faceted in scope. Under the direction of Dr. Doris Hadary at the American University, a curriculum model was developed in which blind, deaf and emotionally disturbed students conducted hands-on activities in both art and science in a mainstream setting. Students who were handicapped were transported to the Horace Mann Elementary School in Washington, D. C. in order to have classes containing handicapped and non-handicapped students together.

The project components of particular concern for this monograph are the development of methods and materials to teach science to students who are visually impaired and the provision of pre-service training to elementary school teachers who will have responsibility for these classrooms. As part of the elementary teacher education program at the American University, college students had opportunities to participate in a practicum in which they worked in these classrooms with students who had special learning needs.

The project modified existing materials and created new ways of using materials so that students who were handicapped could have hands-on science activities. For example, the students used a light sensor to count the number of swings that a pendulum makes. The pendulum produced a momentary break in the continuous auditory signal being produced by the light sensor as it passed through the beam of light directed at the light sensor. In another lesson the students investigated the variations in the amount of light reflected by different surfaces.

Student Science Teaching Program in Marine Science for the Handicapped

This project represents an entirely different kind of effort to improve science education for students with handicaps. Under the direction of Dr. E. C. Keller, this project developed a summer science program in marine science for talented students in 11th and 12th grades who have handicaps. This summer program was conducted at the Marine Science Consortium at Wallops Island, Virginia during the summers of 1977 through 1981. About 25 students who were auditory, orthopedic or visually impaired lived together in barracks as they attended these six week programs. During the summer program the students attended lectures, conducted laboratory activities and had numerous field experiences. Each student also conducted an individual mini-research study during the summer.

The project staff continually worked to devise ways that would enable all the students to participate fully in all aspects in the study of marine science.

The efforts of the project are vividly presented in a 28 minute film entitled "You Can ...", and produced by the National Oceanic and Atmospheric Administration.

During the last summer program about 20 science teachers attended a workshop held in conjunction with the student program. The teachers became familiar with the methods and materials that were being used to teach science to these students. This workshop provided the rationale for compiling the information about teaching science to students who are handicapped. This compilation resulted in the publication of a resource book:

Teaching the Physically Disabled in the Mainstream Science Class at the Secondary and College Levels. This publication describes numerous strategies, both general and specific, that will assist science teachers to accommodate students with auditory, orthopedic, and visual impairments.

But how does a science teacher identify an appropriate strategy to use with a specific student with a visual impairment? All students with visual impairments do not function the same way in a learning situation. Some guidelines for a teacher to use in identifying appropriate methods and materials are presented next.

IDENTIFYING ALTERNATIVE TECHNIQUES

When a student with a visual impairment is identified, the student is generally labeled with one of the following terms: partially sighted, legally blind, functional blind, or blind. In addition, a medical term is frequently included as another way of categorizing the condition. For example, the student may be labeled functionally blind and also said to have retrolental fibroplasia (RLF).

This classification scheme really does not help science teachers identify and select alternative methods or materials so they can make their science instruction accessible to a specific student. Suppose the teacher is told that I am legally blind and have retinitis pigmentosa. This bit of knowledge will be of little use to the science teacher who suddenly finds that I am going to be in his/her chemistry course.

The teacher does need to know if a student functions effectively in learning situations that involve four different levels of tasks:

1. Close-up tasks such as reading a book, drawing a diagram, or using a microscope.
2. Near-by tasks or tasks at an arm's length, such as manipulating objects or handling lab equipment.
3. Distance tasks such as reading what is on the chalkboard or viewing what is on the screen.
4. Mobility tasks such as moving to different places in a lab or going on field trips.

If the teacher has a clear indication of how the student can perform in these tasks, it will be easier for the teacher to identify alternative methods and materials. Three illustrations on how this knowledge can assist the teacher are briefly described on the following pages.

Illustration A. The student is legally blind.

1. Close-up tasks: The student can read the science text and diagrams if normal lighting is maintained. He/she may need additional light in the laboratory room. If additional light is required a study lamp will be adequate.

2. Near-by tasks: The student can efficiently perform all manipulative activities within an arm's length. However, the student has a limited field of vision. It is essential that the work area for the student be well organized, with all unnecessary materials removed.

3. Distance tasks: The student can read what is on the chalkboard and screen. The student can read more effectively if

he/she is not sitting near the chalkboard or screen. The student's narrow field of vision prevents him/her from seeing a large surface area of the chalkboard in one eye fixation if sitting close to it.

4. Mobility tasks: The student will require little assistance on field trips, unless the place is not well lighted or is very congested. In these cases another student can provide assistance. The teacher should not permit the student to move about freely during lab activities.

Illustration B. The student is partially sighted.

1. Close-up tasks: The student cannot read the textbook or diagrams, nor use a microscope effectively. The student can read a large print edition of the text, use audio tapes of supplemental reading materials, and observe diagrams projected by an overhead. The student can observe microscopic projections of 2 x 2 slides or of a microprojector.

2. Near-by tasks: The student can make gross manipulations of large objects that do not require exact eye-hand coordination. In lab activities the teacher should provide a lab assistant or partner to do these kinds of tasks.

3. Distance tasks: The student can read what is on the screen or chalkboard from near the front of the room. The student may use a monocular eye piece. The student can not do these tasks effectively if the chalkboard receives insufficient light.

4. Mobility tasks: The student can perform all mobility tasks without modifications or alternative planning.

Illustration C. The student is functionally blind.

1. Close-up tasks: The student can read a braille text that uses the literacy braille code, but not a text that uses The Nemeth Code for Mathematics and Science Notation extensively. The student can use audio tapes of supplemental reading materials not available in braille. If the local library has a Kurzwell Reading Machine, the student will be able to do some library-type projects. The student will need to use tactile diagrams (diagrams that are read with the finger tips).

2. Near-by tasks: Most all hands-on activities need to be modified, or alternative activities provided for the student. If necessary, a lab assistant or partner should serve as the hands of the student and collector of observations. This assistant should be cautioned not to be the thinker or processor of the observations, and that the student should be the one to mentally manipulate the data collected.

3. Distance tasks: The student cannot see the chalkboard or screen. The teacher should verbally describe or read what is put on the board. Another student can also be asked to verbally describe what others are seeing on the screen.

4. Mobility tasks: The student uses a cane or guide person for mobility purposes. A combination of these methods can be used on field trips. The teacher should restrict the student's movement in congested laboratory setting, and check to be sure the student's cane is located where other students will not accidentally trip over it.

The selection of appropriate accommodations for these students is not finished once it is ascertained how the students

function at these four task levels. It is imperative to remember that students who function similarly in reading, near-by, distance and mobility tasks can differ in other ways. For example, suppose there are two students who have no vision in the same tenth grade biology course. Both students function similarly in all four tasks levels. However, suppose one student has had no vision since birth, while the other student did not lose his/her vision until the age of 11. The latter student will have visual memory of prior experiences to use when studying some concepts in biology, whereas the other student will have no visual memory. Other differences between these students which may also influence their reaction to alternative instructional methods and materials. The students may vary in their interest and aptitude toward science as related in part to their skill and personal drive to cope with their loss of sight.

While the differences among students with visual impairments has been emphasized, there is one common factor that usually exists for most of these students. These students will generally need more time to complete the same tasks that the students without visual impairments are required to do. Students with visual impairments should be given enough time so they have an equal opportunity to demonstrate their competency to do the required task. This does not mean they should receive an unlimited amount of time. Generally the student and teacher should cooperatively establish a suitable time allotment for the completion of a specific task. Unique considerations may be required for assessing the achievement of these students. Such

factors are described fully in the monograph, Testing Physically Handicapped Students in Science (1983).

Thus far, this discussion has not considered ways by which the science teacher can solve the greatest challenge: to provide hands-on or lab experience for students who can not perform the regular activities because of a visual impairment. The next section describes the efforts of science educators to meet this challenge.

PROVIDING HAND-ON AND LABORATORY ACTIVITIES

Many science educators have faced the challenge of devising ways to provide hands-on and laboratory acitivites for students with visual impairments. The nature of these challenges, as well as the solutions, have been very diverse. Illustrations of a few recent efforts are described below. The reader should refer to the sources given in Appendix B to locate descriptions of the ways other persons have met the challenge.

Four different science lessons for general science classes are reported by Billings, Cuphone and Nober (1980). These lessons provide alternative ways of teaching the structure of flowers, the bonding between complementary surfaces of enzyme-substrate reactions, the concept of mass and how to measure it, and the process of meiosis. Most of the activities involved the use of tactile materials made from cardboard, textured fabric, felt, yarn and pipe cleaners. An electric eye is added to a balance beam so when the scale is balanced a light beam is broken and a sound amplifier connected to the electric eye produces a constant

tone. Artificial flowers are used to provide a three-dimensional view of the flower after the students study felt diagrams depicting a cross-section view of a flower.

A magnetic board can be used in chemistry to illustrate Lewis structures, and depict organic molecules (Smith, 1981). The board can be constructed inexpensively from materials found locally. By altering the shapes and configurations of the magnetic pieces, the apparatus has many other potential uses.

Loeb (1981) has designed several chemistry exercises that illustrate chemical reactions. In one exercise the students measure specific amounts of powdered plaster and water, and then mix them. Then the students collect observations about the hardening of the mixture at periodical intervals. The students test the hardness by using finger pressure and trying to lift the mixture by one of ten toothpicks placed in the mixture at the start. The students are also able to detect the heat of reaction with their fingers.

Ricker (1981) reported on several methods of providing alternative microscopic viewing experiences for students with residual vision. These students were unable to use regular microscopes effectively. The following media were tried with several students: microprojectors, closed-circuit TV systems, individual microscope viewing screens, the Micro-Side Viewer, and rear-viewing screens with two-by-two slide transparencies. The effectiveness of the methods varied with the specific needs of the individual student. For one student who was sensitive to light the use of the negative image projected by a closed circuit TV system was effective. The use of the Micro-Slide-Viewer was also

an effective method for this same student since very little light is required to use this instrument.

Ricker and Rodgers (1981) described several techniques that can be used to modify existing instructional materials so tactile input is provided to the visually impaired students. For example, when pop-it beads are used in simulation activities to study chromosomal behavior, usually two different colors of beads are used to distinguish between homologous chromosomes. A sighted student can follow the exchange between sister chromatids in meiosis by observing the colors of the beads. So the student with a visual impairment can also follow this exchange, thumb tacks can be inserted in all the beads of one color. The students can then trace this aspect of meiosis with their fingers.

Tactile diagrams are essential for providing students continuous access to information. Ricker and Benefield (1981) designed tactile diagrams for teaching biology that were inexpensive and durable. Multiple copies of the master diagram were made with the American Thermoform Brailon Duplicator. By making multiple copies it was possible to give each student his/her own copy for continuous reference. The diagrams were used by students to follow an instructor's lecture, to present information that sighted students gained in the laboratory through visual observations, and for assessing student achievement.

The staff at Macrolab, New Jersey Institute of Technology, has designed a variety of devices that enable students who are visually impaired to function in a science laboratory (Hinchliffe and Skawinski, 1983). One such device is a modified spectrophotometer that permits a student to analyze the

wavelengths of light produced by a burning sample, and therefore, determine the chemical composition of the sample. In essence the visual system is altered to increase the linear dispension of light and to reduce the amount of field to be examined at one time; and then an audio system is added so the light signals are converted to auditory signals so the student can control the instrument and also collect data by using a tactile scale.

One of the first attempts to use computer technology to make science laboratories accessible has been done by Lunney and Morrison (1981). They were faced with the challenge of making chemistry courses accessible to a student with no vision. They developed a laboratory instrument that would provide voice and tone output. Their efforts led to the creation of ULTRA system. While the development of this system continues, it has already been interfaced with various sensors and instruments (e.g. titrators, digital balances, ph electrodes, visible spectrophotometers) to allow the student to collect data. The student uses a keyboard to control the data collection process. The student hears the output in synthesized speech or in audio tones.

An overview of some of the innovations described above, as well as many other innovations that have reported during the past three decades, have been described in an article by Cetera, "Laboratory Adaptations for Visually Inpaired Students: Thirty Years in Review" (1983). The reader is referred to the references included in this article for detailed descriptions of how science educators have sought to make their science laboratories accessible to these students.

As teachers plan ways to provide hands-on science activities, they need to be concerned with the aspect of safety. A student with visual impairment should not automatically be denied the opportunity of having these kinds of learning experiences just because of the impairment. Persons frequently assume that hands-on activities will create a dangerous situation for both the student and others in the room. (Swanson and Steere, 1981). Some factors that teachers can consider in establishing good practices to establish safe classrooms and laboratories are discussed next.

SAFETY CONSIDERATIONS

All science teachers have the obligation to enforce good safety practices in their classes for all the students, whether there are or are not students with handicaps in their classes. If a teacher does have a student with a visual problem in class, it means that specific factors have to be considered so the safety procedures incorporate any unique needs. The factors described below will help the teacher identify some situations in which unique needs may exist. The solutions to these situations will ultimately depend on each individual case. As described in an earlier section, students with visual impairments function differently in close-up, near-by, distant and mobility tasks.

1. Mobility and Orientation. The student should receive specific instruction about the physical arrangement of the classroom and laboratory. At any time this arrangement is altered the student should be re-oriented to these changes. Special considerations should be given to the development of specific procedures on how the handicapped student and his/her classmates

should respond to an emergency in the laboratory or when the school fire alarm rings. If the student uses a cane or dog guide for mobility, procedures for being sure that the cane or dog is accessible to the student, but located in a safe place should be established.

2. Using new instruments and techniques. The student should receive training in handling and using an unfamiliar instrument or technique. Some circumstances may dictate that the student be required to do a dry-run simulation before doing the actual activity. For some specific situations it may be necessary to assign a lab assistant to the student with a visual impairment. In these instances the lab assistant should serve as the eyes and hands of the student so the required observations can be collected. However, the lab assistant should not mentally manipulate the collected data. The student should be responsible for doing this task.

3. Work stations. The student should receive orientation in regard to the space at which he/she will work. This work space should be well organized and with all unnecessary materials removed. It is essential that certain objects be labeled for identification purposes. Large print labels can be made by using a felt pen, large print typewriter, or large print hand-embosser. Braille labels can be made on transparent adhesive tape with a slate and stylus, a braille writer, or a braille hand-embosser.

Whenever possible it is advisable to use distinctly colored and textured containers for specific purposes. For example, a bright red wash type bottle with a vertically ribbed surface can be used to indicate if the contents of the container are

flammable. If a container does not have a distinct shape or surface texture and there is a need to be able to readily identify it, a texture can be added to the outside of the container. Two bands of sandpaper around a glass container of acid will alert the student to this fact when the container is touched. For the students who cannot read braille or large print this may be the only means for them to recognize that they have picked up a container of acid.

When students have a wet-lab, the use of vinyl sleeve protectors and aprons should be considered as partial protection against accidental spillage.

4. Face and eye protection. This aspect of safety must not be ignored. Face protections is of paramount importance. It may be necessary to have some students with visual handicaps wear protective goggles when not normally considered essential for other students. In some cases, particularly for students with no vision, face shields should be considered as a means of protecting the face. With either limited or no eye sight, the students lack the normal reflex actions that other students have. (Ricker, 1981).

As teachers make their science classes accessible to students with visual impairments, they should be ready to recognize those students who have an aptitude and interest in science. These students should be encouraged to consider science, or science-related, careers as a future goal. These students should realize that such careers are not impossible. Some illustrations of persons who have pursued science-related careers are described below.

CAREER EDUCATION IN SCIENCE

The intent of this section is to emphasize the need for science educators to encourage students who have the aptitude and interest in science to consider the field of science for a future career. The students who are visually impaired should be aware of the existing achievements of persons in science as an indication that the existence of a visual impairment does not mean the field of science is closed to them.

In 1978 the American Association for the Advancement of Science published a directory of handicapped scientists (Owens, Redden & Brown, 1978). Of the 500 plus persons identified in this directory there are over 100 persons who are visually impaired and pursuing a science-related career. More recently, the Foundation for Science and the Handicapped, Inc., has sponsored the publication of Able Scientists-Disabled Persons by Phyllis Stearner (1984). This publication provides biographical sketches of 27 persons who have science-related careers and also some type of handicap (auditory, mobility, visually, and learning disability). The sketches of persons with visual impairments include a computer programmer, mathematican, rehabilitation researcher, physicist, and clinical psychologist.

The possibility of becoming a science teacher is also a potential career goal. The first edition of the National Directory of Blind Teachers (National Association of Blind Teachers, 1983) identifies 227 of the estimated 1700 teachers in the United States who are visually impaired. The Directory

includes 20 teachers who are in the field of mathematics, natural sciences and electronics.

Five short descriptions of persons who have had or are presently pursuing science-related careers are presented below to illustrate the variety of achievements of persons with visual impairments.

Ralph R. Teetor

Mr. Teetor, blind from the age of five, obtained bachelor's and master's degrees in engineering in the early 1900's. During his professional career he received credit for numerous inventions. His most notable invention was called the "Speed-O-Stat". This device, now known as the "Cruise Control", is a common device on many automobiles. (Hicks, 1982)

Geerat Vermeij

Professor Verneij, blind as an infant, exhibited an interest in studying science as an elementary school student. Neither his parents or teachers attempted to discourage his interest in biology. He did encounter resistance to his career ambitions while in undergraduate school. However, these obstacles were overcome and he eventually went on to graduate school where he received a Ph.D. degree in biology. Professor Vermeij joined the faculty of the University of Maryland where he has become an instructor and researcher in the field of zoology (Achievement in Science, 1978).

David W. Hartman

Mr. Hartman, blind since the age of 8, decided to become a medical doctor at the age of 14. He continually encountered negative reactions from schools and society as he resolutely

stayed with his ambition to be a doctor. After finishing undergraduate school he entered medical school at Temple University. After receiving his medical degree, Dr. Hartman spent his two years of hospital residency specializing in physiatry (rehabilitative medicine) and psychiatry. Dr. Hartman is now a practicing psychiatrist (Hartman & Asbell, 1978).

Teddy L. Barber

Mr. Barber lost over 95% of his vision at the age of 16. His interest in science led to a major in optical and atmospheric physics in undergraduate school. After starting work at the federal Atmospheric Science Laboratory at the White Sands Missile Range, he entered graduate school to obtain a master's degree in physical chemistry. Mr. Barber has continued to work at the Laboratory where he conducts research studies in remote atmospheric sensing technology (Stearner, 1984).

Maria Dolores Cimini

Ms. Cimini began losing here eyesight when she was 16 as a result of congenital glaucoma. She received less and less encouragement from her teachers to continue pursuing her interests in science. Rather she sensed the development of negative attitudes about her abilities and future. After entering college Ms. Cimini acquired an interest in psychology. At the same time she received encouragement and positive feedback from her instructors. As she pursued a major in psychology she investigated what adaptations would be necessary for her to be a clinical psychologist. After obtaining a bachelor's degree, she entered graduate school to obtain a Ph.D. degree in clinial psychology. Ms. Climini is presently completing this program,

after which she wants to teach at the college level and conduct research (Stearner, 1984).

Detailed biographical sketches of these five persons would reveal that a wide range of coping strategies or adaptations have been used by these people, particularly in their educational studies. The specific adaptations that they have made were determined, in part, by the availability of certain technological aids or devices.

During the last decade a large number of aids and devices have been developed to enhance the teaching of science to students with visual impairments. The development of computer technology represents one aspect of this period of development. The potential use of this technology to help make science education accessible to these students is discussed below.

USING COMPUTER TECHNOLOGY

The application of computers in science education is being promoted throughout the country. Science teachers are beginning to use microcomputers to provide a variety of learning activities: practice and drill, tutorial or self-instruction, laboratory simulations, and problem-solving experiences. If a conscious effort is not undertaken, it is possible to exclude students with visual impairments from these learning activities. A typical microcomputer learning station requires the student to have sufficient vision to read the output information shown on the monitor or a print copy done by a regular printer.

Thus, a primary concern for using microcomputer with these students is the need to have alternative output modes. For some

students this could mean that a large print microcomputer system needs to be used. For example, a large print monitor system is available so the print displayed on the monitor can be increased up to 16 times its original size. Large print display processors are currently available for APPLE II computers and the IBM-PC computer (Visualtek Re News, 1984).

For other students it might be necessary to attach a speech synthesizer to the microcomputer to obtain oral output. The student can monitor what he/she types on the keyboard and also what appears on the monitor. While the hardware exists to provide oral output there are very few science software programs written in such a way that is possible to use a speech synthesizer effectively.

In addition, the use of graphics in a program presents another problem. A speech synthesizer does not describe a graphic display. If the software program is not written to include a special description, the graphics will be inaccessible to a student who is not able to visually interpret the screen.

Research is presently being conducted on the development of a tactile graphic board that can be interfaced with a microcomputer (Maure, 1983). Such a display board would provide tactile output so the student can read charts, graphs and diagrams with his finger tips. In addition, the board would display a full page of reading material in braille.

Due to these current problems concerning the lack of adequate software which provides effective oral output and hardware to have tactile graphic, the use of interactive computer assisted instruction for many students with visual impairments is limited.

At the present time a more practical use of computer technology is the production of print materials in large print and braille formats. Teachers can provide the students with readable materials which have not been readily available in the past. For example, the acquisition of worksheets in braille depended on the availability of a braille transcriber and adequate time for it to be prepared. By using computer technology the need to have a human braille transcriber can be eliminated and the time factor greatly reduced. It also means that in certain situations students may do their homework in braille and a microcomputer used the next day in school to convert the students' homework into regular print for the classroom teacher to correct. And conversely, the teacher's assignments can be converted from regular print to braille by using computer technology (Moore, 1983).

The reader is referred to the following two issues of the Aids and Appliances Review for detailed descriptions of devices that provide braille and voice output for computers. These reviews are published by The Carroll Center for the Blind, 770 Centre Street, Newton, MA 02158.

1. Aids and Applications Review, Issues No. 9 and No. 10, Summer and Fall 1983, "Voice Output for Compter Access by the Blind and Visually Impaired".
2. Aids and Appliances Review, Issue No. 11, Winter, 1984, "Braille and Computers".

Summary

A basic premise on which this monograph was written is: Students with visual impairments are not different from students without visual impairments, once the visual impairments are removed. In other words, among a population of students who are visually impaired there will be high to low achievers, students with a variety of talents, students with high to low academic aptitudes, students with excellent to poor coordination, and students with high to low motivation. Teachers must guard against over-generalizing about students with visual impairments. If one student has a difficult time reading braille, it does not mean all students will. Or if a student has excellent manipulative skills in the science lab, it does not mean all students will be able to do the same manipulations with equal facility.

A second basic premise is: Science teachers are not trained to be specialists in the teaching of students with handicaps. This monograph was not written in an attempt to help science teachers become specialists. Rather the goal of this monograph was to increase the awareness of science teachers to the unique needs to students who are visually impaired. In addition, an attempt was made to describe some illustrative methods and materials for teaching science to these students. With this information teachers can be more effective in identifying the special needs of individual students and seeking assistance from specialists and professional agencies concerned with the education of students with visual impairments. It will be a great challenge

to a science teacher, but it will not be an unsurmountable challenge. Its solution will be exciting and rewarding.

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APPENDIX A

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APPENDIX B

RESOURCES

A. American Association for the Advancement of Science (AAAS). 1515 Massachusetts Avenue, N. W., Washington, D.C. 20005

The Office of Opportunities in Science of the AAAS has several kinds of publications:

1. Resource Directory of Handicapped Scienctists. The Directory identifies the names and pertinent information on 500 plus handicapped scientists. The 1978 edition of the Directory is presently being revised. The Directory can be used by teachers to identify persons who may be able to serve as role models for students.

2. Out of School Programs in Science. This publication provides a listing of out-of-school science-related programs throughout the country. It is designed to be a resource for identifying activities in which students who have interest in science may participate. Students, both handicapped and non-handicapped, can broaden their understanding of science in such programs.

3. Bulletins on Science & Technology for the Handicapped. This bulletin is published 4 times a year as a means of disseminating current information on science and technology that relates to the education, careers and daily living experiences of handicapped persons.

B. American Chemical Society, 1155 Sixteenth Street, N. W., Washington, D. C. 20036.

The Committee on the Handicapped of the ACS has prepared a resource booklet entitled "Teaching Chemistry to Physically Handicapped Students".

C. HEATH, American Council on Education, One Dupont Circle, Suite 780, Washington, D. C. 20036.

HEATH (Higher Education and the Handicapped) has published several resources for educators. Among the resources the most pertinent to science education is: "Access to the Science Laboratory and Classroom". This phamplet identifies sources of materials and techniques for making science programs accessible

to physically handicapped students.

D. National Science Teachers Association, 1742 Connecticut Avenue, N. W., Washington, D. C. 20009

The National Science Teachers Association (NSTA) has a Special Education Advisory Board that is concerned with the role of NSTA in enhancing science education for all handicapped students. In 1979 NSTA published a source book on teaching science to physically handicapped students. Since then it has published numerous articles in its three journals: Science and Children, The Science Teacher, and Journal of College Science Teaching.

1. Sourcebook: Science Education and the Physically Handicapped. Washington, D. C.: National Science Teachers Association, 1979.

E. Science for the Handicapped Association. Dr. Ben Thompson, Secretary-Treasurer, Department of Elementary Education, University of Wisconsin at Eau Claire, Eau Claire, WI 54701

The Association publishes a newsletter twice a year in which sources of information on teaching science to handicapped students are identified. The Association also produces a 41 page bibliography that is up-dated yearly. An annotated bibliography was published under the sponsorship of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education in December, 1980. The publication, edited by Ben Thompson, is entitled Science for the Handicapped: An Annotated Bibliography. Its ERIC accession number is ED 196 721.